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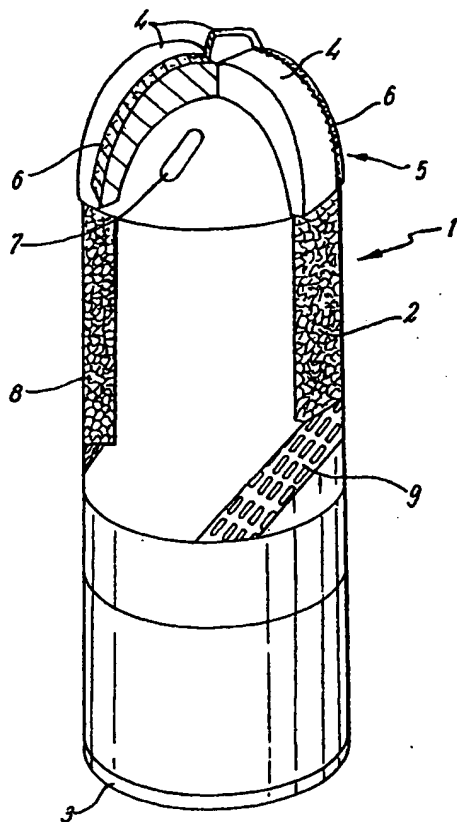
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[Continued on next page]

(54) Title: DRILLING BIT FOR DRILLING WHILE RUNNING CASING

(57) Abstract: A drill bit for drilling casing in a well bore. The drill bit is constructed from a combination of relatively soft and relatively hard materials. The proportions of the materials are selected such that the drill bit provides suitable cutting and boring of the well bore while being able to be drilled through by a subsequent drill bit. Methods of applying hard materials to a soft material body are provided.



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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## DRILLING BIT FOR DRILLING WHILE RUNNING CASING

1

2

3 The present invention relates to drilling tools as are  
4 typically used for drilling well bores.

5

6 Conventionally, when drilling a well bore of the type used  
7 in oil or gas production, a string of drill pipe having a  
8 drill bit on the lower end thereof is advanced into the  
9 ground. As the drill is advanced into the ground it  
10 encounters different rock formations, some of which may be  
11 unstable. To minimise problems which may be incurred by  
12 running the drill bit from one formation to another, it is  
13 common practice to run the drill bit to a predetermined  
14 depth, and then remove or "trip" the drill string from the  
15 bore. Structural casing, typically made of heavy steel  
16 piping, is then lowered into the bore and cemented in place  
17 when set. The casing acts as a lining within the bore, and  
18 prevents collapse of the newly drilled bore or  
19 contamination of the oil or gas reservoir.

20

21 As a consequences of having to carry out the above  
22 procedure, the cost and time taken to drill a bore is

1 increased as it is necessary to perform a number of trips  
2 down the well. It will be appreciated that at the  
3 considerable depths reached during oil and gas production  
4 the time taken to implement complex retrieval procedures to  
5 recover the drill string can be very long, and accordingly  
6 the beginning of profitable production can be greatly  
7 delayed.

8

9 An attempt has been made to mitigate this problem with the  
10 introduction of a procedure known as "drilling with  
11 casing". This procedure relies on the attachment of a  
12 drill bit to the actual casing string, so that the drill  
13 bit functions not only to drill the earth formation, but  
14 also to guide the casing into the well bore. This is  
15 advantageous as the casing is pulled into the bore by the  
16 drill bit, and therefore negates the requirement of having  
17 to retrieve the drill string and drill bit after reaching a  
18 target depth to allow cementing.

19

20 While this procedure greatly increases the efficiency of  
21 the drilling procedure, a further problem is encountered  
22 when the casing is cemented upon reaching the desired  
23 depth. The advantage of drilling with casing is that the  
24 drill bit does not have to be retrieved from the well bore.  
25 However as a result, should drilling to a greater depth be  
26 required after cementing the casing, the subsequent drill  
27 bit has to pass through the previous bit in order to  
28 advance. This is extremely difficult as drill bits are  
29 required to remove hard rock material and are accordingly  
30 very resistant and robust structures typically manufactured  
31 from materials such as Tungsten Carbide or steel.  
32 Attempting to drill through an old drill bit may result in

1 damaging the new drill bit, adversely affecting the  
2 efficiency of any further drilling. Consequently, the  
3 damaged drill bit would have to be retrieved from the bore  
4 and replaced, and the time and cost advantage gained by  
5 using the drilling with casing procedure would be lost.

6

7 It would therefore be a distinct advantage to provide a  
8 drill bit for use during drilling with casing which can  
9 drill rock and earth formations but which can also be  
10 drilled through by another drill bit. The provision of a  
11 drill bit which allows the passage of a subsequent drill  
12 bit through it, would reduce the number of trips into a  
13 well bore required during a normal drilling procedure and  
14 minimise the risk of damaging any further drill bits  
15 introduced into the bore.

16

17 In our prior Patent Application PCT/GB99/01816 we have  
18 suggested that the drill bit has hard drilling material  
19 that may be moved away from the remaining body of the drill  
20 shoe prior to subsequent drilling through of the drill bit.  
21 We have also proposed EP0815342, a drill bit or shoe having  
22 hard drilling material placed only on the drill shoe or bit  
23 at the peripheral circumference thereof, and specifically  
24 only at the sides of the drill bit or shoe where the  
25 diameter is greater than the internal diameter of the  
26 casing. The present invention is distinguished from both of  
27 these teachings in that it provides for a drill shoe or bit  
28 that has hard material within the area below the internal  
29 boundaries of the casing, and does not require moving parts  
30 to be displaced before subsequent drilling through can be  
31 commenced.

32

1

2 It is an object of the present invention to provide a drill  
3 bit for use in a well bore which can drill earth and rock  
4 formations and guide a casing string into a well bore  
5 simultaneously.

6

7 It is a further object of the present invention to provide  
8 a drill bit for use in a well bore which is constructed  
9 from a material which allows a second drill bit to drill  
10 through it.

11

12 It is a yet further object of the present invention to  
13 provide a drill bit for use in a well bore which allows a  
14 second drill bit to drill through it, such that the second  
15 drill bit is not damaged and can progress beyond the point  
16 reached by the original drill bit within the well bore.

17

18 According to a first aspect of the present invention there  
19 is provided a drill bit for drilling with casing in a well  
20 bore, said drill bit being constructed from a combination  
21 of a relatively soft material and a relatively hard  
22 material, wherein the hard material is suitable for cutting  
23 earth or rock, and wherein the combination of materials is  
24 in such proportion and in such arrangement to allow a  
25 subsequent further drill bit to drill through it.

26

27 Preferably the drill bit is substantially constructed from  
28 the relatively soft material, wherein the relatively soft  
29 material is adapted to be drilled through with a standard  
30 earth drill bit.

31

1 Preferably the drill bit is formed with a body having or  
2 being associated with a nose portion upon which are cutting  
3 members, wherein the body is made substantially from the  
4 relatively soft material and at least the leading edge or  
5 cutting surface of each cutting member is made from the  
6 hard material.

7  
8 Preferably the hard wearing material is a hard material  
9 such as tungsten carbide or a superhard material such as  
10 diamond composite or cubic boron nitride although any other  
11 suitable material may be used.

12  
13 Preferably the soft, drillable material is aluminium.  
14 Alternatively the soft drillable material is copper or  
15 brass alloy, although any other suitable material could be  
16 used.

17  
18 There may be a plurality of soft materials and there may be  
19 a plurality of hard materials.

20  
21 In one possible embodiment the nose is directly coated with  
22 the hard wearing material.

23  
24 Optionally the coating is a continuous layer or film that  
25 covers the surface of the nose.

26  
27 Alternatively the coating is non-continuous, such that the  
28 nose is afforded areas which are not coated by the hard  
29 wearing material, wherein upon rotation of the drill bit  
30 the cumulative effect of the coated areas gives complete  
31 circumferential coverage of the dimensions of the drilled  
32 hole.

1

2 Alternatively the coating may be applied to an intermediate  
3 which is amenable to the nose of the drill bit.

4

5 Preferably the intermediate is nickel.

6

7 The intermediate may be attached to the nose prior to  
8 coating with the hard wearing material. Optionally the  
9 intermediate may be coated with the hard wearing material  
10 prior to attachment to the nose.

11

12 In a second embodiment the hard wearing material is applied  
13 to the nose in the form of preformed elements wherein the  
14 cumulative effect of said preformed elements is to cover  
15 the surface of the nose and so act as a coating thereof.

16

17 The preformed elements may be chips or fragments of the  
18 hard material.

19

20 The preformed elements of the hard material may be directly  
21 applied to the nose.

22

23 Alternatively the preformed elements of hard material are  
24 applied to the nose following the application of an  
25 amenable intermediate material to the nose or the preformed  
26 elements.

27

28 Preferably the amenable intermediate material is nickel  
29 substrate.

30



1 The preformed elements may be attached to the nose by  
2 standard techniques such as brazing, welding or shrink  
3 fitting.

4

5 Optionally the preformed elements have a re-enforced  
6 structure to aid drilling of hard formations. Where the  
7 preformed elements have a re-enforced structure, preferably  
8 the preformed elements are pre-weakened prior to attachment  
9 to the nose in order to allow fracture of the preformed  
10 elements upon drilling.

11

12 Preferably the drill bit may also comprise a plurality of  
13 flow ports to allow fluid bypass and lubrication of the  
14 bit.

15

16 Preferably the drill bit also comprises a stabiliser or  
17 centraliser.

18

19 Preferably the drill bit also comprises reaming members.

20

21 According to a third aspect of the present invention there  
22 is provided a method of fixing a hard or super hard wearing  
23 material to a drill bit nose made of a soft drillable  
24 material, wherein a jet is used to blow gases at very high  
25 speeds towards a cast of the nose and particles of the hard  
26 or superhard wearing material are introduced into the gas  
27 stream, wherein the kinetic energy of the procedure is  
28 converted to thermal energy which welds the particles to  
29 the nose.

30

31 According to a fourth aspect of the present invention there  
32 is provided a method for fixing a hard or superhard wearing

1 material to a drill bit nose made of a soft drillable  
2 material, wherein particles of the hard or superhard  
3 wearing material are placed within a mould and thereafter  
4 the soft drillable material is poured in molten form into  
5 the mould, such that on cooling said hard or superhard  
6 wearing particles are set in situ.

7

8 Alternatively the hard wearing material can be fixed to the  
9 nose by a standard technique such as brazing, welding and  
10 electroplating.

11

12 In order to provide a better understanding of the  
13 invention, example embodiments of the invention will now be  
14 illustrated with reference to the following Figures in  
15 which;

16

17 Figure 1 illustrates a drill bit in accordance with the  
18 present invention;

19

20 Figure 2 is an elevated view of the top of the drill bit;

21

22 Figure 3 illustrates an individual cutting member isolated  
23 from the drill bit.

24

25 Figure 4 illustrates an elevated view of the top of an  
26 alternative embodiment of a drill bit in accordance with  
27 the present invention; and

28

29 Figure 5 illustrates a pre-formed element for attaching to  
30 the nose portion of a drill bit.

31

1 Referring firstly to Figure 1, a drill bit generally  
2 depicted at 1, is comprised of a cylindrical body 2, that  
3 can be mounted on the lower end of a casing string (not  
4 shown) via a thread end connection 3 that can mate with the  
5 casing. The drill bit 1 is further comprised of a  
6 plurality of cutting members 4 which are fixed to the  
7 opposite end of the body 2 to the thread end connection 3,  
8 namely the nose end 5. The cutting members 4 extend out  
9 from the nose end 5.

10

11 The nose 5 and cutting members 4 are constructed from a  
12 material such as aluminium, copper or brass alloy which is  
13 soft enough to allow the aforementioned nose 5 and members  
14 4 to be drilled through by a second and subsequent drill  
15 bit (not shown). The cutting members 4 are substantially  
16 covered by a relatively hard material 6 typically being a  
17 hard material such as tungsten carbide or a superhard  
18 material such as diamond composite or cubic boron nitride.  
19 In the depicted embodiment the relatively hard material 6  
20 is located at the "leading edge" of the cutting member 4.  
21 In this respect the "leading edge" refers to the side of  
22 the cutting member 4 which directly contacts the ground or  
23 rock upon rotation of the drill bit 1. It is recognised  
24 that whilst in the depicted embodiments the hard wearing  
25 material is afforded to the leading edge of one or more  
26 cutting members 4 on the drill bit 1, the invention is not  
27 limited to this configuration. For example the hard  
28 wearing material may be applied to the nose 5 in an  
29 embodiment having no cutting members 4 or may be applied to  
30 the whole surface of the cutting members 4.

31

1 The relatively hard material 6 may be applied to the  
2 cutting members 4 or nose 5 as a coating, that is as a  
3 layer or film. In one embodiment a continuous layer of the  
4 material 6 may cover the entire surface of the nose 5, or  
5 the cutting members 4. Alternatively a non-continuous  
6 layer of the material may coat the nose 5 or cutting  
7 members 4. In this instance, the surface of the nose 5 or  
8 cutting members 4 will comprise areas that are not coated.  
9 However, upon rotation of the drill bit 1, the cumulative  
10 effect of the coated areas will be complete circumferential  
11 coverage of the inside diameter of the casing in which the  
12 drill bit is located.

13

14 It is recognised in the present invention that direct  
15 application of some coatings to the nose material may not  
16 be practical. For example, extremely hard tungsten carbide  
17 particles cannot be applied to the preferred nose materials  
18 (e.g. aluminium or copper) by lasercarb welding. This  
19 material can be applied to soft nickel, however machining  
20 said drill bit 1 entirely from nickel would be unduly  
21 expensive. Therefore in an alternative embodiment, a  
22 coating of the hard material 6 is applied to an  
23 intermediate, typically being nickel substrate, which is  
24 then attached to the nose 5 of the drill bit 1.  
25 Alternatively the nickel substrate can be attached to the  
26 nose 5 prior to coating.

27

28 In a further embodiment preformed elements of the hard or  
29 superhard material 6 are applied to the nose 5 or cutting  
30 members 4 of the drill bit 1 in place of a coating of film.  
31 Said preformed elements may be chips, or fragments of the  
32 hard material 6. Typically the cumulative effect of the

1 preformed elements is to cover the surface of the nose 5 or  
2 the cutting members 4 and so act as a coating thereof. The  
3 preformed elements may be directly applied to the nose 5 or  
4 cutting members 4 or may be applied after applying an  
5 amenable material either to the nose 5 or cutting members 4  
6 or the preformed element itself. The amenable material is  
7 typically nickel substrate.

8

9 The layout of cutting members 4 can be seen more clearly in  
10 Figure 2 which shows the nose end 5, viewed from above, and  
11 in Figure 3 which shows an individual cutting member 4. It  
12 can be seen in Figure 3 that the cutting means 6 has teeth  
13 formations 10 which allow any "chips" of material remaining  
14 in the well bore to pass through the blade structure.

15

16 The nose 5 further comprises flow by areas 7 that allow  
17 fluid circulated within the well bore to lubricate the  
18 surfaces of the bit 1. The body 2 also comprises a  
19 stabiliser or centraliser 9 which maintains the drill bit  
20 in the centre of the well bore, and reaming members 8,  
21 which function to remove any irregularities or obstructions  
22 from the wall of the bore.

23

24 In use, the drill bit 1, is run into a well bore (not  
25 shown) from the surface, typically whilst being rotated.  
26 The drill bit 1 pulls a casing string (not shown) as it is  
27 advanced into the newly formed well bore to a predetermined  
28 depth. Upon reaching this depth, the casing is cemented to  
29 strengthen the lining of the bore. If drilling beyond this  
30 first assembly is required, a second drill bit of a smaller  
31 diameter to the first is run into the well inside the  
32 casing string from the surface.

1  
2 Upon reaching the first assembly, the new drill bit can  
3 drill through the soft drillable material of the original  
4 drill bit 1 and cutting members 4, and therefore can  
5 proceed to a point beyond the depth reached by the original  
6 drill bit 1 within the well bore. The hard or super hard  
7 material 6 fixed to the cutting members 4 of the original  
8 drill bit 1 disintegrate into shavings when drilled. The  
9 shavings released into the well bore when the original bit  
10 1 is drilled through do not obstruct the bore and are  
11 therefore not detrimental to the subsequent drilling  
12 process. In this manner a further section of the bore can  
13 be drilled beyond the previously attained depth without  
14 damage to the new drill bit and without needing to retrieve  
15 the first assembly from the bore.

16  
17 When used for drilling through harder formations a thicker  
18 section of the preformed element will be required. However  
19 it will be appreciated that in such an instance, said  
20 preformed elements would not be drillable. Thereby in the  
21 event that a thicker element is required, said element is  
22 typically pre-weakened prior to attachment to the nose 5 or  
23 cutting members 4. In this manner, the elements will have  
24 the attributes of high stiffness whilst drilling but low  
25 resistance to fracture whilst being drilled. The pre-  
26 formed elements can then be applied directly to the nose 5  
27 or cutting members 4 by brazing or shrink-fitting or could  
28 be attached to an amenable material, typically nickel  
29 substrate.

30  
31 A first method for fixing the hard or superhard material 6  
32 is now outlined. A jet is used to blow gases at very high

1 speeds towards a cast or block of the cutting member 4 or  
2 nose 5, and which is made from the soft, drillable  
3 material. Typically a speed in the region of Mach 2 is  
4 used. Very fine particles of the hard or superhard wearing  
5 material are introduced into the gas stream. The resulting  
6 kinetic energy is converted to thermal energy in the  
7 particles, and accordingly the heated particles "weld" to  
8 the leading edge of the cast or block therefore forming a  
9 thin layer or film.

10

11 It will be appreciated that the abovedescribed method could  
12 be used with particles of the hard or superhard material,  
13 or with intermediates coated by the hard or super hard  
14 material or with preformed elements as described above.

15

16 An alternative method for fixing preformed hard or  
17 superhard particles to the cutting members 4 is to place  
18 them within a drill mould. Molten drillable soft material  
19 that will eventually become the nose 5 of the drill bit 1  
20 is then poured into the mould. On cooling the metal  
21 provides a drill bit 1 that has the hard or superhard  
22 particles set in situ.

23

24 The present invention is inherent with significant  
25 advantages in that the time taken for the drilling  
26 operation can be greatly reduced as there is no need to  
27 implement complex and timely retrieval operations to  
28 recover apparatus from the bore. As a result the  
29 profitable stage of production can be begin much sooner.

30

31 A further advantage, is that unlike the drill bits known to  
32 the art, the drill bit of the present invention is

1 drillable by another drill bit and the risk of damage to  
2 the second drill bit is therefore reduced. Furthermore as  
3 the cutting means of the cutting members consist of fine  
4 layers or cutting elements formed from hard material, they  
5 disintegrate into shavings upon drilling and therefore do  
6 not act as an obstruction to any subsequent apparatus that  
7 is advanced into the well.

8

9 Further modifications and improvements may be incorporated  
10 without departing from the scope of the invention herein  
11 intended.



1 Claims:

2

3 1. A drill bit for drilling with casing in a well bore,  
4 said drill bit being constructed from a combination of  
5 a relatively soft material and a relatively hard  
6 material, wherein the hard material is suitable for  
7 cutting earth or rock, and wherein the combination of  
8 materials is in such proportion and in such  
9 arrangement to allow a subsequent further drill bit to  
10 drill through said drill bit.

11

12 2. A drill bit as claimed in Claim 1 substantially  
13 constructed from the relatively soft material, wherein  
14 the relatively soft material is adapted to be drilled  
15 through with a standard earth drill bit.

16

17 3. A drill bit as claimed in Claim 1 or Claim 2 formed  
18 with a body having or being associated with a nose  
19 portion upon which are cutting members, wherein the  
20 body is made substantially from the relatively soft  
21 material and at least a leading edge or cutting  
22 surface of each cutting member is made from the  
23 relatively hard material.

24

25 4. A drill bit as claimed in any one of the preceding  
26 Claims, wherein the hard material is tungsten carbide.

27

28 5. A drill bit as claimed in any one of Claims 1 to 3,  
29 wherein the hard material is diamond composite.

30

31 6. A drill bit as claimed in any one of Claims 1 to 3,  
32 wherein the hard material is cubic boron nitride.

1

2 7. A drill bit as claimed in any one of the preceding  
3 Claims wherein the soft material is aluminium.

4

5 8. A drill bit as claimed in any one of Claims 1 to 6,  
6 wherein the soft material is copper or brass alloy.

7

8 9. A drill bit as claimed in any one of the preceding  
9 Claims having a plurality of soft materials.

10

11 10. A drill bit as claimed in any one of the preceding  
12 Claims having a plurality of hard materials.

13

14 11. A drill bit as claimed in any one of the preceding  
15 Claims wherein the hard material is provided as a  
16 coating.

17

18 12. A drill bit as claimed in Claim 11 wherein the coating  
19 is applied to the nose portion.

20

21 13. A drill bit as claimed in Claim 11 or Claim 12 wherein  
22 the coating is a continuous layer or film.

23

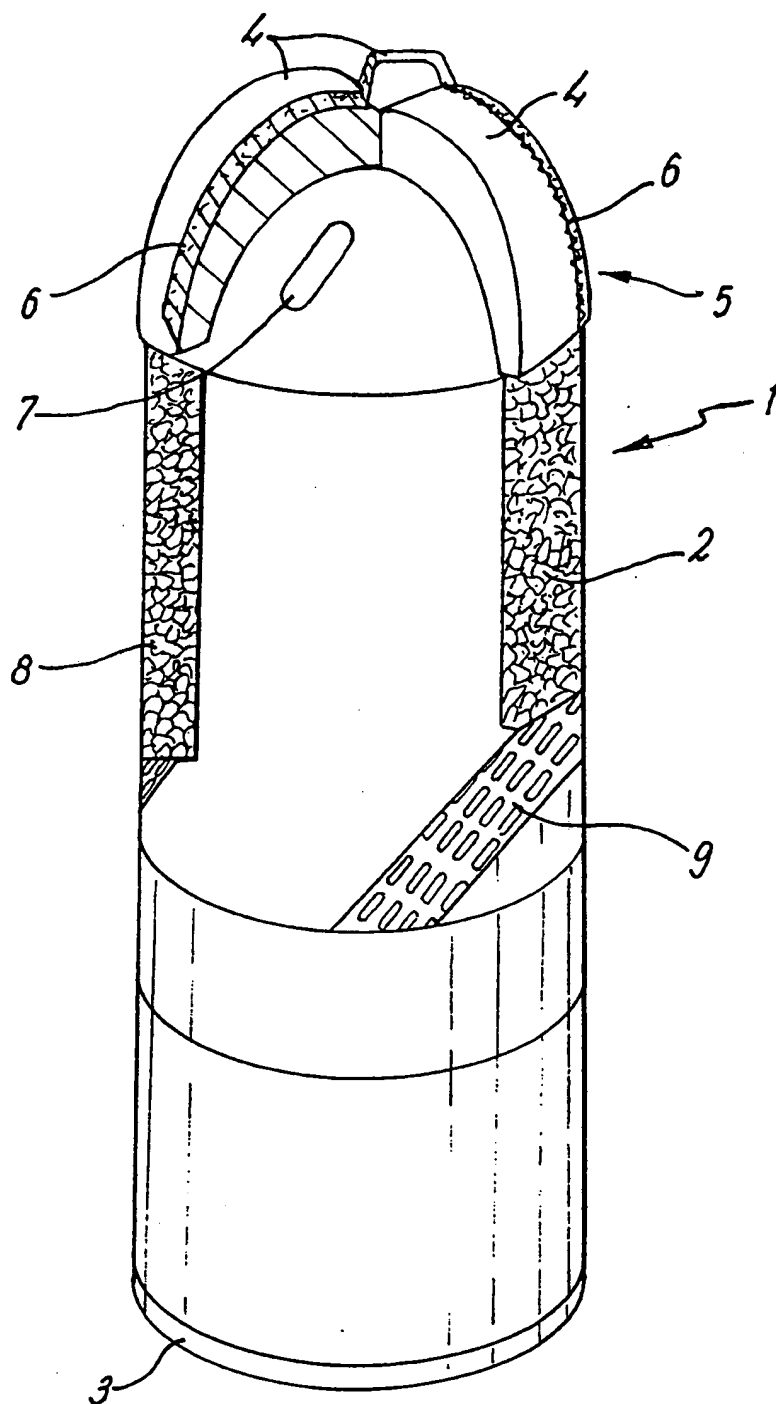
24 14. A drill bit as claimed in Claim 11 or Claim 12 wherein  
25 the coating is non-continuous, such that surfaces of  
26 the drill bit are afforded areas which are not coated  
27 by the hard material, wherein upon rotation of the  
28 drill bit, the cumulative effect of the coated areas  
29 gives complete circumferential coverage of the  
30 dimensions of the drilled well bore.

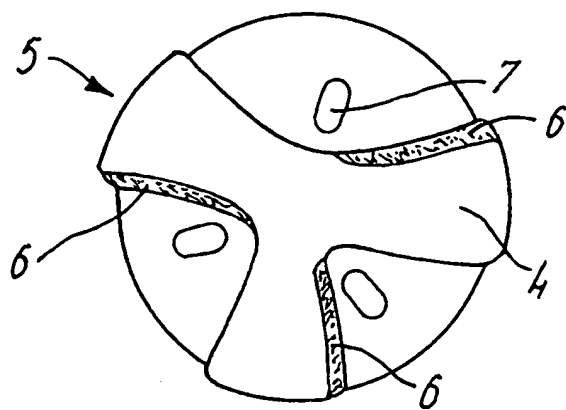
31

- 1 15. A drill bit as claimed in any one of the preceding  
2 Claims wherein the hard material is applied to an  
3 intermediate which is amenable to the nose of the  
4 drill bit.  
5
- 6 16. A drill bit as claimed in Claim 15 wherein the  
7 intermediate is nickel.  
8
- 9 17. A drill bit as claimed in any one of Claims 1 to 10  
10 wherein the hard wearing material is applied to the  
11 nose as preformed elements wherein the cumulative  
12 effect of said preformed elements is to cover the  
13 surface of the nose and so act as a coating thereof.  
14
- 15 18. A drill bit as claimed in Claim 17 wherein the  
16 preformed elements are chips or fragments of the hard  
17 material.  
18
- 19 19. A drill bit as claimed in Claim 17 or 18 wherein the  
20 preformed elements are attached to the nose by  
21 brazing.  
22
- 23 20. A drill bit as claimed in any one of Claims 17 to 19  
24 wherein the preformed elements have a reinforced  
25 structure to aid drilling of hard formations.  
26
- 27 21. A drill bit as claimed in Claim 20 wherein the  
28 preformed elements are pre-weakened prior to  
29 attachment to the nose in order to allow fracture of  
30 the preformed elements upon drilling.

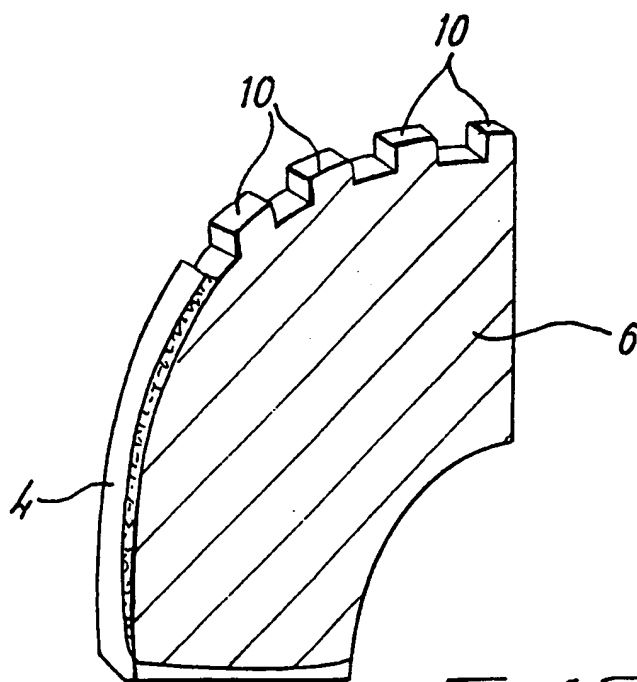
- 1 22. A drill bit as claimed in any one of the preceding  
2 Claims also comprising a plurality of flow ports to  
3 allow fluid bypass and lubrication of the bit.  
4
- 5 23. A drill bit as claimed in any one of the preceding  
6 Claims also comprising a stabiliser or centraliser.  
7
- 8 24. A drill bit as claimed in any one of the preceding  
9 Claims also comprising reaming members.  
10
- 11 25. A method of fixing a hard or super hard wearing  
12 material to a drill bit nose made of a soft drillable  
13 material, wherein a jet is used to blow gases at very  
14 high speeds towards a cast of the nose and particles  
15 of the hard or superhard wearing material are  
16 introduced into the gas stream, wherein the kinetic  
17 energy of the procedure is converted to thermal energy  
18 which welds the particles to the nose.  
19
- 20 26. A method for fixing a hard or superhard wearing  
21 material to a drill bit nose made of a soft drillable  
22 material, wherein particles of the hard or superhard  
23 wearing material are placed within a mould and  
24 thereafter the soft drillable material is poured in  
25 molten form into the mould, such that on cooling said  
26 hard or superhard wearing particles are set in situ.  
27
- 28 27. A method for drilling a well bore comprising attaching  
29 a drill bit in accordance with any one of the  
30 preceding Claims to casing, drilling a bore through  
31 the earth formation and subsequently running a further

- 1 drill bit in the well inside the casing and drilling
- 2 through the first drill bit.
- 3

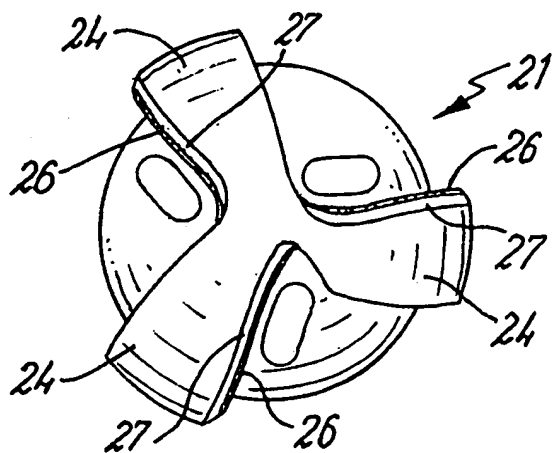
**Fig. 1**



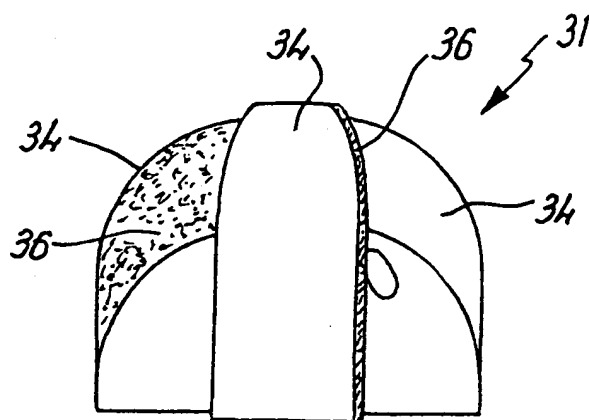
**FIG. 2**



**FIG. 3**



**FIG. 4**



**FIG. 5**



# INTERNATIONAL SEARCH REPORT

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**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 E21B7/20 E21B10/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 957 225 A (SINOR LAWRENCE ALLEN) 28 September 1999 (1999-09-28) column 5, line 15 - line 20  column 6, line 5 - line 12 column 13, line 37 - line 40 column 13, line 57 - line 60; figures 6A, 6B, 7	1, 3, 5, 9, 22, 27 4, 6-8, 11-19, 23-26
Y	US 5 096 465 A (CHEN SY-HWA ET AL) 17 March 1992 (1992-03-17) column 1, line 27 - line 30 column 10, line 44 - line 49  -/-	4, 6



Further documents are listed in the continuation of box C.



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Date of the actual completion of the international search

6 March 2001

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

In International Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	WO 96 28635 A (BRIT BIT LIMITED ;STRONG PHILLIP (GB); WARDLEY MICHAEL (GB)) 19 September 1996 (1996-09-19) cited in the application page 7, line 30 - line 36 page 8, line 28 - line 34; figure 3 ---	7,8,23, 24
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